Computational Thinking Practices at Play in an Early Childhood Microworld

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Abstract: Recently there has been increased interest in exploring computational thinking (CT) concepts and practices in preK-12 teaching and learning. Few studies, however, have explored how CT learning experiences are implemented in play-based early childhood classrooms. The current study explored the design and implementation of a hands-on and play-based microworld in preschool classrooms. Framed in the context of a professional development program with Head Start educators, we designed an activity to engage preschoolers in designing and building mazes for a bristlebot bug to navigate. We collected data in the form of classroom observations, teacher surveys, and interviews. Findings showed that children engaged in CT practices as they collaboratively designed and modified paths for the bug to travel. These findings suggest that microworlds with carefully chosen physical objects may give preschoolers opportunities to develop CT practices while experiencing the benefits of free and collaborative play.

Introduction

Research has suggested that engaging young children in computational thinking (CT) can lead to positive attitudes toward computing and the development of CT skills (Israel et al., 2015). Studies have shown that some of the core concepts of CT such as sequencing, algorithmic thinking, and debugging may provide children unique opportunities to apply their creativity and problem solving skills (Bers et al., 2014; McCormick & Hall, 2022). CT experiences have also been shown to help young learners develop both social and motor skills as well as increase competency in other academic subjects (Hunsaker et. al., 2019).

Studies have focused on identifying the essential elements of CT for teaching and learning within the elementary grades (Yadav, Hong, & Stephenson, 2016), as well as teachers’ conceptions of developmentally appropriate CT instruction for young children (Rich, Yadav, & Schwartz, 2019). However, more work is needed to adequately examine the opportunities for CT in play-based early childhood classrooms (McCormick & Hall, 2022). This is especially important, given that efforts to articulate developmentally appropriate practices for learning suggest that young children should “engage in sustained play, investigation, exploration, and interaction with adults and peers” (NAEYC, 2009, p. 18). Play-based learning environments are well-suited to provide opportunities for CT practices such as those outlined by Brennan and Resnick (2012): (1) being incremental and iterative, and (2) testing and debugging. In their recent review, however, McCormick and Hall (2022) found that few studies have examined children’s free play with CT tools. Given that many early childhood educational programs view children’s play as an essential component of development and learning, more research is needed on children’s play-based CT experiences. The present study seeks to understand the potential of play-based CT experiences to support young children’s engagement with computational thinking practices.

Theoretical framework

Play-based CT experiences draw on the affordances of play-based learning that offers children opportunities to explore materials, repeat ideas, and follow emergent goals. Vygotsky (1978) proposed that in play, children develop their own rules and norms as they negotiate their actions based on situational constraints, such as limits imposed by physical objects or environments. Play provides opportunities for children to voluntarily engage in activity, encounter constraints, and resolve them in playful and imaginative ways. Guided play (Weisberg et al., 2016), as a middle approach between didactic instruction and free play, suggests that adults can actively and intentionally support children’s learning through co-play, questioning, and reflecting with children during play. Guided play centers children’s agency and interest in the play experience, while offering teachers opportunities to advance learning goals.

We also draw on interactive constructionist microworlds (Papert, 1980) as contexts for offering children play-based opportunities to develop computational thinking practices. “A microworld, like a playground, is a subset of reality that presents itself with structures carefully chosen to encourage children to encounter a particular set of powerful ideas” (Bers, 2020, p. 34). We see potential for microworlds with physical objects to align with play-based early childhood environments as they allow children to explore freely, follow emergent goals, test and repeat their ideas, and problem solve.
Methods
This study is part of a larger professional development (PD) project that introduced preschool educators to play-based activities to support their own developing understanding of CT. In turn, educators then implemented and adapted these activities in their Head Start classrooms with preschoolers (ages 3-5). For this study, we explored how one of the activities—a designed microworld—engaged preschoolers in two CT practices proposed by Brennan and Resnick (2012): (1) being incremental and iterative, and (2) testing and debugging. In this paper, we describe the design and implementation of the microworld and report initial findings from our implementation.

Setting, participants, and professional development
A total of 26 Head Start preschool teachers and teacher-assistants participated in the PD project. These educators teach a total of 131 preschoolers in eight classrooms, each classroom having between two to four teachers.

We organized the PD into five modules, with each module spanning one month of the calendar year and focusing on a different theme: patterns, spatial communication (including directional language), movement, board games, and programming robots. Each module included a two-hour PD session, follow-up classroom coaching, and activities for classroom and home use. In each module, teachers and children were encouraged to use natural, intuitive, and play-based ways to explore ideas.

The microworld activity described in this study was nested in the robots module and was centered around a bristlebot bug. The bristlebot is a simple robot that uses a vibrating motor and rubber bristles to move around in a bug-like manner and is confined to the environment in which it travels. The microworld environment for the bug is created as a maze with various construction materials such as blocks, DUPLO bricks, cardboard tubes, clear tubes, and other found objects. Teachers first explored the microworld and bristlebot bug during the two-hour PD session before implementing the activity in their classrooms. Throughout the month, teachers encouraged children to explore the bristlebot bug and use the construction materials to create a maze for their bug (See Figure 1). Children programmed the bug by designing physical constraints; as children modified the constraints, the bug’s movement changed.

Figure 1
*Opportunities for Constructive Exploration within the Bristlebot Bug Microworld*

Data sources and analysis
We collected data in the form of written PD reflections from teachers, notes from classroom observations, photos and videos of children’s activity, and teacher interviews. We used interpretivist methods to understand how teachers and children engaged in CT practices when exploring the microworld. We then used thematic analysis to code and categorize children’s activity.

Findings
Our findings are organized around children’s use of CT practices when exploring the microworld, including how they playfully engaged with the bug and the environmental materials. We also describe what teachers noticed about children’s activity and their own facilitation through the lens of one participating teacher’s observations.

As children were introduced to the bristlebot bug, they quickly became acquainted with the bug’s movement. When holding the bug in their hands, children were delighted with the quirky and unpredictable movement. When placed on the table or the floor, the bug quickly moved in random directions, with children often trying to corral the bug with their hands. The other materials available to children, such as wooden blocks, were then introduced by teachers as potential environmental constraints or boundaries that could guide the bug’s movement (See Figure 2).
In creating their mazes, children engaged in *incremental and iterative* activity as they began to assemble materials to guide the bug (Table 1). They found that certain materials were helpful in moving the bug in a straight direction forward, while other combinations of materials allowed for right or left turns. In one instance, a group of four children connected tubes sequentially to provide a long path for the bug. In doing so, they explored the potential of narrow paths to guide movement toward a desired location. Wider spaces, in contrast, allowed for random movement and turn-arounds (this type of movement seemed more “buglike” and delightful to children). During their play, children engaged in spatial communication and dialogue as they explored what materials to use to accomplish their goal. Teachers noticed that children incrementally tried things out based on their ideas, then adapted their constructions based on their experiences. Teachers also encouraged children to attend to the physical resources in their planning, such as suggesting that children make the bug travel according to the directional arrows marked in the half-tube shown in the lower right corner of Figure 2.

### Table 1

**Correlation of Bristlebot Bug Microworld to CT practices (Brennan & Resnick, 2012)**

<table>
<thead>
<tr>
<th>CT Practices</th>
<th>Evidence from Children’s Activity</th>
<th>Evidence from Teacher Interviews</th>
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<td>being incremental and iterative</td>
<td>Children designed mazes for bugs in parts, adding sections onto existing structures and adapting existing mazes based on evidence from prior mazes</td>
<td>“I just put the materials out, and I just left them there… and said, ‘How are we going to do this?’ you know, instead of constructing it for them…and they were like, ‘Well, we could do this, and we could,’ it was like, it just stimulated their brain to figure it out.”</td>
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<td>testing and debugging</td>
<td>Children tested how various materials affected the bug’s movement and fixed existing problems; for example, when the bug’s path was interrupted between tubes, children used painter’s tape to connect tubes</td>
<td>“Um the children also, too, they would always bring in different supplies, ‘Well, let's try this,’ you know, ‘well let's try that,’ um, so they have their own ideas, and brought in their own ideas and experiences, too.” “They will set up like, different toys, put it around there, and just put the bugs, the hex bugs, and see if they are going through, or are they going into the tube, or they can’t escape from the table when they put a toy blocking it like a maze.” “A little girl came up and said, ‘We can do races with those tunnels, with the bugs,’ you know, and so that was interesting. She came up with that, ‘so we could make a maze on top of the tunnel, and, um, we can see if the bugs can go through.’”</td>
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A second CT practice observed was *testing and debugging*. This practice was evidenced when children were pursuing particular goals and their constructions did not work exactly as intended. For example, when children wanted to see how far they could make the bug travel, they arranged a path with materials, released the
bug to travel the path, collected the bug, rearranged or modified the path, then re-released the bug. Other small groups of children worked through trial and error efforts as they created races with other bugs.

**Discussion and implications**

Our findings suggest that the designed microworld engaged young children in computational thinking practices as they programmed their bug through the physical construction of a microworld maze. In contrast to CT robotic experiences which require a programmer to direct a robot by telling it how to move, the bristlebot bug microworld required children to introduce environmental constraints. We suggest that the microworld served as a rich playground for the merging of computational thinking practices with play-based learning affordances; for example, our findings showed numerous instances of children’s playful repetition as a catalyst for *incremental and iterative* maze construction. In addition, children’s pursuit of emergent goals led to cycles of *testing and debugging*. For teachers, the microworld provided opportunities to engage with children during play in ways that supported children’s iterative processes and constructions.

One particular line of research worth pursuing further involves the careful selection of physical materials within the microworld. Because the bug microworld engaged children in hands-on play with physical materials only, we are interested in examining the role of these materials themselves as action-oriented substructures. Rather than using symbolic features such as arrows to communicate commands, the physical materials themselves became associated with actions: the clear or cardboard tubes caused straight and efficient movement; “L” shaped constructions made from DUPLO blocks caused turns; “U” shaped corrals constrained the bug but allowed for exit; square shaped configurations constrained the bug indefinitely. As such, the physical materials of this particular microworld show promise in serving as intermediary bridges between the physical and symbolic. Other materials may provide for additional variations to maze construction, such as inclines and declines.

Our future work will continue to examine the designed features of this microworld, as well as others, to help us further understand the opportunities young learners have to engage in CT practices in play-based learning settings.

**References**


NAEYC. (2009). *Developmentally appropriate practice in early childhood programs serving children from birth through age 8*.


